ACHIEVEMENTS OF THE EGYPTIAN IRON EXPLORATION PROJECT (IEP, 1993-1997)

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This report which summarizes the main goals, methodology, achievements and results of the Egyptian Iron Exploration Project (IEP, 1993-1997), is presented here on behalf of the research groups. The relevant documents are included in the reports of phases I, II and III, and are accessible at HCMI, ISCO, EGSMA and the Geology Department, Cairo University.

Egypt entered the field of iron and steel production in the I 950's. Aswan iron ore was shipped to the Iron and Steel Company (ISCO) at Helwan, about 900 km north of Aswan. The Complex was established close to the Nile River and Helwan residential area, near Cairo. Pollution problems were not addressed at that time. During the 1960's news were circulated about the discovery of iron ore deposits surpassing those of Aswan. These deposits occur to the north of the El Bahariya Oases in the Western Desert, about 300 km west of Helwan. The Iron and Steel Complex switched to the El Bahariya Oases for iron ores, and Aswan was abandoned.

In the 1990's, it was predicted that Egypt would face shortages in iron and steel production . New iron ore reserves were sought to secure the national economy. Several meetings, symposia and conferences were held to find a solution to this serious issue. In 1992, the Metallurgical Industries Corporation and the Ministry of Petroleum and Mineral Resources agreed to sign an agreement with Cairo University and the Egyptian Geological Survey and Mining Authority (EGSMA) to search for new iron ore deposits in Egypt.

The goal of the signed project is iron ore exploration based on geological merit, in Aswan and El Bahariya Regions. Figures I and 2 illustrate the different phases of iron exploration in these regions. The first phase of the IEP was to assess all previous studies and to visit all iron ore occurrences in the country. The working groups (Table 1) succeeded in identifying the nature of the problem, and proposed the plan of action for the second and third stages of the project. The field and laboratory activities of the IEP, conducted by EGSMA and Cairo University Groups, are shown in Table 2.

The future of iron ore mining in Egypt is bright and the evaluation of the deposits will indicate the optimum conditions for exploitation of the newly discovered iron ores. Incidentally, it is worth mentioning that President MUBARAK paid a visit to the newly discovered iron ores in the area southeast of Aswan. Investors are being invited to exploit these deposits in the light of the recent technologies for iron and steel production. The strategy of phase I was to conduct regional mapping on a scale of I : 25000, and to prepare a

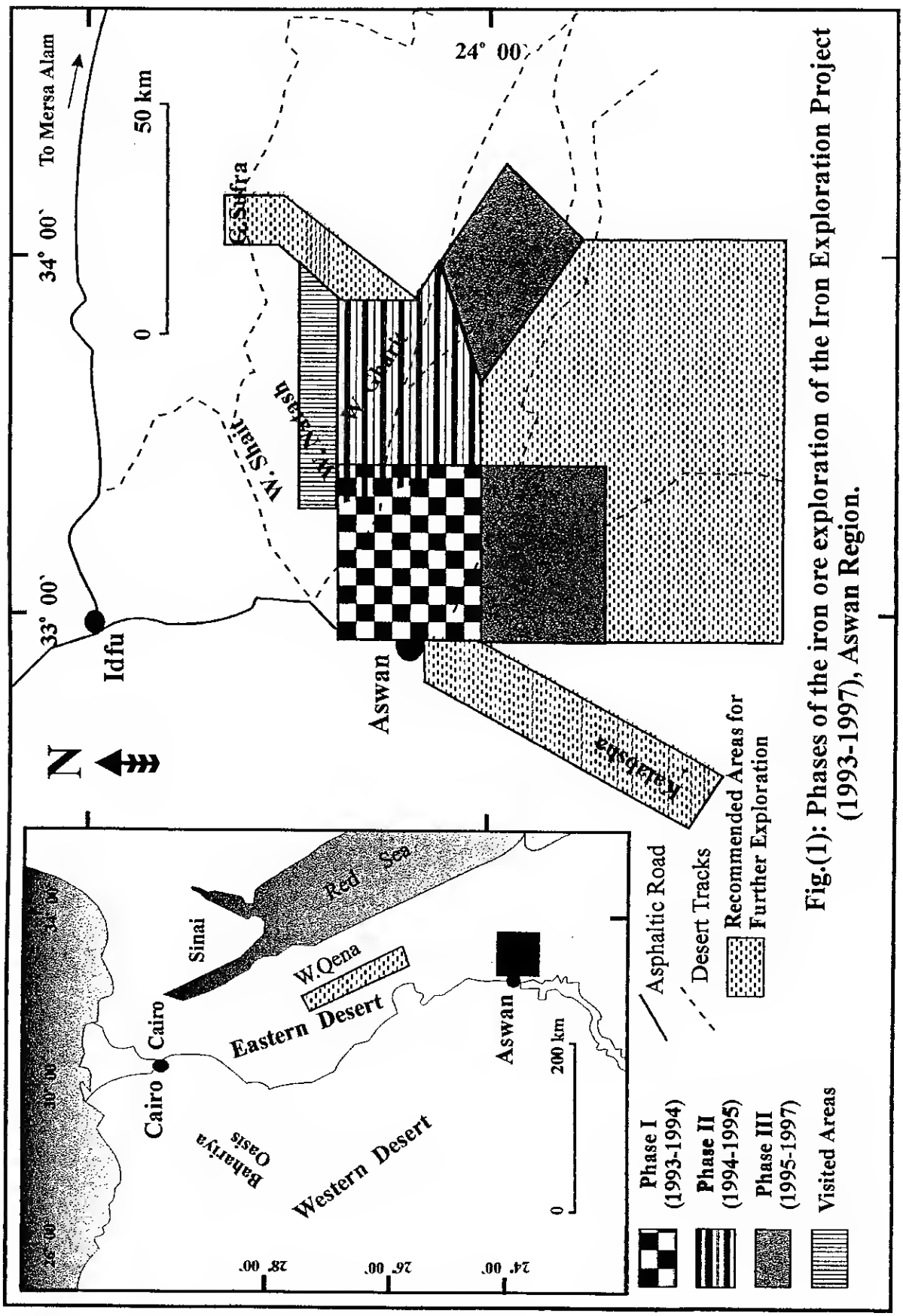

Fig.(1): Phases of the iron ore exploration of the Iron Exploration Project (1993-1997), Aswan Region.

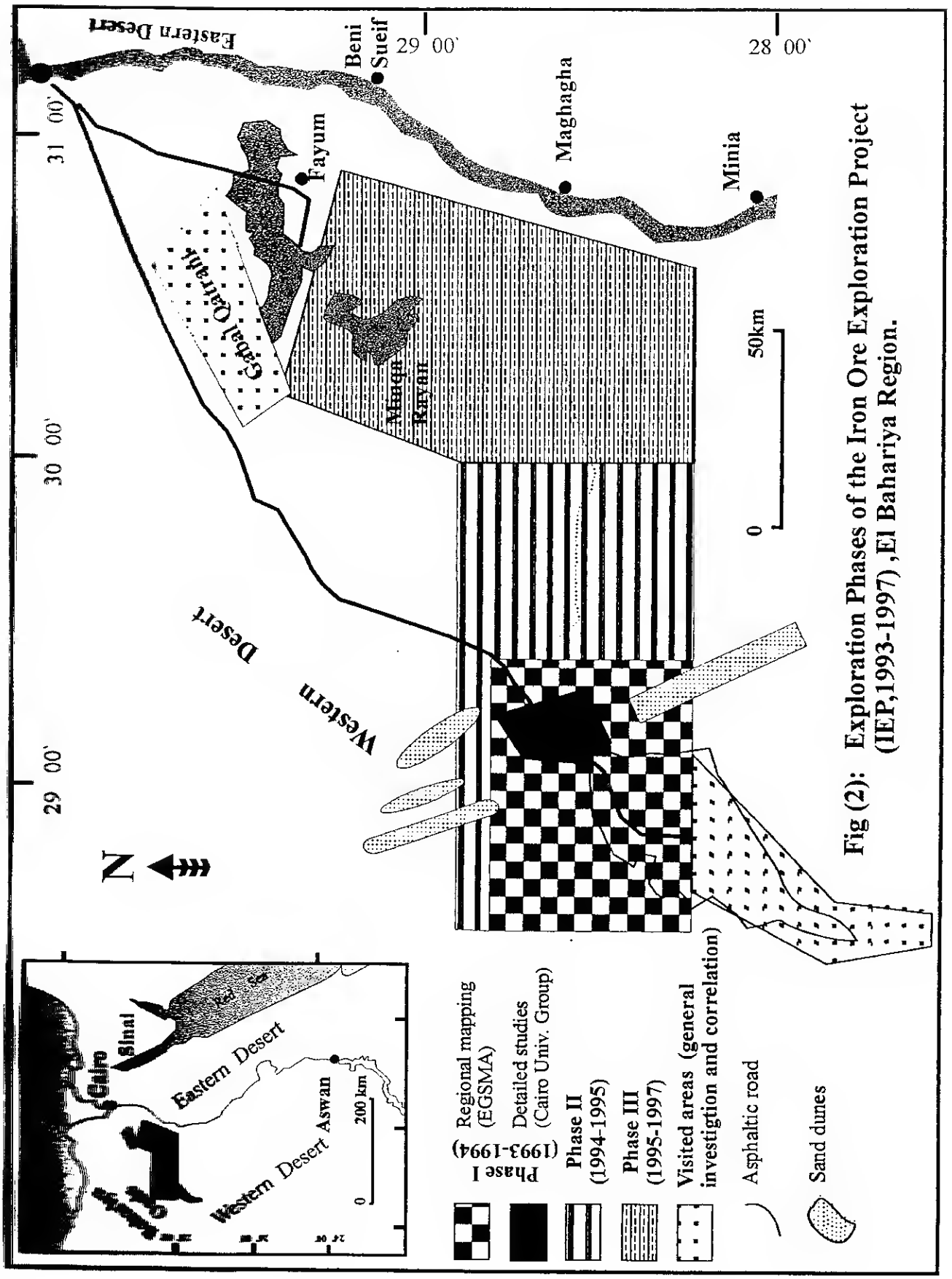

Fig (2): Exploration Phases of the Iron Ore Exploration Project (IEP,1993-1997) ,El Bahariya Region.

Table (1)

Geological Survey of Egypt (EGSMA) | **Metallurgical Industries Co. (MICOR)** | **Cairo University, Geology Department**

IEP Groups

Mr..GNAIM; Leader of the Consortium

Prof. Dr. M. A. EL SHARKAWI; Principal Investigator

EGSMA GROUP

Geologist M. El Hinnawi

Geologist A. Mazhar

Geologists

El Bahariya

Dr. M. El Balasy
Mr. N. Ibrahim
Mr.U. Abdel Aal

Aswan

Mr. M. Sleem
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Mr. Zoil
M.A. Abdel Karem

Dr. B. El Hakiem

Geophysicists

Mr. A. El Sorady
Mr .F. Shata
Mr. A. Ismail

CAIRO UNIV.GROUP

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Dr. A. Sehim
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Dr. A. Helba
Dr. A. Mesaed

Cnsultant

Prof. Dr. M. L. Abdel Khalek

Participant Geologists:

Mr. Qurani Mr. Madani Dr. A. Abdel Moteleb
Dr. N. El Barkooky Ms. Fatma El Zahraa

Table (2) IEP, Field and Lab. Activities (Phases I – III).

Field works & Laboratory Techniques	Phase I (1993 – 1994)				Phase II (1994 – 1996)				Phase III (1996 – 1997)			
	Aswan Region		El Bahariya Region		Aswan Region		EL Bahariya Region		Aswan Region		El Bahariya Region	
	EGSMA	Cairo Univ.	EGSMA	Cairo Univ.	EGSMA	Cairo Univ.	EGSMA	Cairo Univ.	EGSMA	Cairo Univ.	EGSMA	Cairo Univ.
1. Field Activities:												
* Surveyed & Mapped Areas (km^2)	1700	-	5540	1388	1100	982	7191	200	3252	1342	9625	-
* Reconnaissance (km^2)	-	400	-	950	-	1200	-	500	-	900	-	1900
* Stratigraphic Sections (No. / metrage)	1	5/450	-	16/480	88/2468	13/325	39/549	-	102	12/120	15/400	7/210
* Trenches (No. / metrage)	64/2314	-	32/816	5/150	48/1162	9/82	-	5/50	847.66	28/224	-	-
* Structural, Subsurface, & Geomorphological maps (No.)	-	-	-	11	-	4	1	10	-	3	-	5
* Correlations (No.)	1	1	-	3	6	2	46	-	-	2	-	2
* 2-d & 3-d models (No.)	-	1	-	7	-	-	-	-	-	-	-	1
* Bore Holes (No. / metrage)	-	-	-	-	7/502	-	19/533.6	-	4/60	-	38/1570	-
* Samples collected (No.)	736	197	54	224	564	150	853	661	347	130	304	632
* Megascopic Examinations (No. of samples)	736	197	54	224	564	150	853	661	347	130	304	632
* Re-evaluation of Ore Reserves (No./km^2)	-	-	-	-	4/501	-	-	-	-	-	-	-
* New discoveries & Geological Evaluation (No. / km^2)	-	-	-	-	-	1/6.3	2 / 1		8	2 / 15	1 / 3	1 / 3
* Field photographs (No.)	-	150	-	300	70	200	100	350	150	200	150	200
* Technological Samples (No.)	-	-	-	-	-	-	-	-	156	-	-	-
2. Laboratory Studies:												
* Palaeontologic Examination(No.)	101	30	-	122	364	-	-	-	-	-	62	-
* Thin Section Examination(No.)	169	235	54	79	236	100	43	160	40	174	72	30
* Polished Section Examination (No.)	-	59	-	40	-	100	112	100	20	90	-	30
* Photomicrographs (No.)	-	40	-	-	-	200	-	60	20	185	-	-
* Mineral Separation (No.)	-	25	--	20	-	-	-	-	-	-	-	-
* XRD/Mineral Analysis (No.)	-	46	23	-	-	-	-	-	-	22	-	-
* Thermal Analyses (No.)	-	-	3	-	-	-	-	-	-	-	-	-
* Spectral Analyses & SEM (No.)	-	22	34	-	-	-	-	-	-	10	-	-
* Specific Analyses (No.)	-	-	2	-	30	-	-	-	-	-	-	-
* Mechanical Analyese (No.)	-	-	2	-	-	-	18	-	-	-	-	-
* XRF & Wt %.	14	35	54	-	192	-	145	-	186	-	-	-
* Cartography (No.)	4	3	20	32	146	90	131	18	100	15	4.9	20
* Reports	Phase I Report				Phase II Report				Phase III Report			
3. Paleomagnetic studies			10/379									
4. Geophysical Studies							1214/4km				3809/8km	
5. Well Logging							355.1					

combined map on a scale of 1 : 100 000. Previous work was revised, and the maps were prepared aiming to:

1. Clarify the field relationships between the different stratigraphic units which crop out in the examined areas of El Bahariya and Aswan.
2. Define geological and tectonic settings of the stratigraphic units which host the iron ores, in El Bahariya and Aswan Regions.
3. Determine the thickness of the iron ore bands by: (a) measuring thicknesses of the iron bands at the outcrops in the studied areas, (b) digging trenches and pits, and (c) selection of the best target areas for drilling bore holes to follow the subsurface extensions of the iron beds.
4. To determine the grade of the iron ore by laboratory techniques.

To achieve reliable mapping, the stratigraphy of both El Bahariya and Aswan Regions was the concern of both the EGSMA and Cairo University Groups. Therefore, joint field visits to exchange views and revise the known stratigraphy were planned and achieved during the progress of phase I of the study. Stratigraphic sections and trenches were prepared and measured, and the data communicated to the other working Group.

To understand the stratigraphic column properly, the structural framework of both regions had to be well constructed, and this was the task of the Cairo University Group.

New structural maps were prepared, especially for El Bahariya region, which was found to be more complicated than earlier realized. The structure is complicated, and hence the stratigraphy, by the interference of igneous activities in this region. The nature of the intrusive and extrusive rocks received careful attention, and paleomagnetic studies for assigning reliable ages to these igneous bodies were conducted by the Paleomagnetic department of EGSMA. The obtained results helped greatly in revising the modes of occurrence of the iron ores and the timing of igneous intrusion.

Following the presentation of the phase I results of the IEP, on Monday, 11th April 1 994, both the EGSMA and Cairo University Groups were engaged in regional mapping, detailed studies of selected sectors as well as excavations, trenching and drilling activities. The nature of the problem of searching for new iron ore occurrences was well understood, and this reliable concept was behind the successful results enclosed in the phase I report. The second phase of the IEP was oriented to fulfil two main goals:

1. Regional mapping of selected areas in El Bahariya and Aswan Regions (Figs. 1 &2), using a scale of 1 : 25000 for the plateau area, northeast of El Bahariya Depression, including El Bahr Depression, and a scale of 1:50 000 for East Aswan- Allawi district, west Aswan - Kalabsha sector and Wadi Garara sector. The geologic mapping focused on the stratigraphic setting and structural configuration of the concerned areas.
2. Regional exploration for the prospective occurrences of iron ore-bearing sedimentary sequences. In that context, the fundamental geologic aspects of the iron or host rock sequences in the El Bahariya (Upper Cretaceous-Middle Eocene) and Aswan (Upper Cretaceous) Regions were considered. This led to major assignments for new discoveries of iron ores in both regions.

The integration of the surface geologic data supplemented by the subsurface information from drilling and geophysical studies and mineralogical investigations during phases I and II

activities, revealed a certain number of geologic parameters/processes that act collectively in the formation and distribution scenario of the iron ore in both El Bahariya and Aswan Regions. The IEP work groups used the guide features of these parameters in evaluating the planned areas of phase III and predicting their prospective sectors. The fundamental geologic parameters and their effective roles in discovering new occurrences of iron ore in Aswan and El Bahariya Regions are outlined as follows.

Aswan Region

1. An exploration approach was adopted in Aswan in order to predict and evaluate the Cretaceous oolitic ironstone in the planned areas south and southeast of Aswan. From phase I and II prospection and discoveries, it was concluded that the economic oolitic ironstone beds commonly terminate the 2nd, and 3rd coarsening- upward cycles of the marine clastic sequence of the Coniacian- Santonian Timsah Formation.
2. The oolitic ironstone is recorded from Wadi Abu Subeira in the North to Wadi Um Bisili in the Southeast, Wadi Road Fl Kabsh in the East, and Barqet Tokham in the south, in beds of variable thicknesses, ranging from discrete laminae (few cm thick) to amalgamated beds up to 3m thick. Such variations occur from place to place, even locally within the same outcrop; but generally, wherever the oolitic beds occur, the clastic section assumes a coarsening-upward organization, and includes characteristic *skolithos* and marine trace fossils.
3. The present distribution of the Timsah Formation and its oolitic iron ore is mainly controlled by a set of NW-SE tensional faults. These faults dislocate the Cretaceous rocks of East and SE Aswan into a system of alternating NW-SW grabens and horsts with tilted fault blocks.
4. Based on these important observations, the exploration plan in phase III was oriented to delineate the fault blocks in which the Timsah Formation is exposed at the surface with a thin veneer of the overlying Um Barmil Formation (as overburden), also, to inspect the formation sedimentologic affinity and heirarchy, whether of marine or fluvial regime. Fortunately, these parameters were realised in El Dabaa block, west of Road El Kabsh, and south of Aswan along the Aswan - Allaqi asphaltic road, at the occurrences of km 21, km 23, East Um Hibal, North and Central Wadi Arab, East Wadi Arab, Barqet Tokham and end of Khur Rahma. The pre-1976 recorded ore reserves of Aswan, and the newly discovered and re- evaluated reserves by the IEP (1993- 1997), are shown in Table 3.

El Bahariya Region

Six geologic factors are recognized including:
1) Cretaceous wrench faulting, (2) Lutetian and Bartonian facies types and lateral changes, (3) Syn and post- Lutetian exposure and consequent karstification, (4) Syn-Bartonian exposure and lateritization, (5) Stratiform setting of the Cenomanian ironstone, and (6) Post-Eocene extensional faulting and formation of discrete grabens.

In phase III, the east El Bahariya areas comprising Darb El Rayan, Darb El Masaudi, Darb El Bahnassawi, terminating at the Nile Valley, were planned for iron ore exploration. These areas represent the normal eastern extension of the Lutetian and Bartonian iron-hosting rocks of the Bahariya region, and also the trend of the NE-SW Cretaceous wrench faulting.
Unfortunately, the interpreted unique geologic setting and its marker features which are

intimately related to the above-mentioned interlocked geologic processes, are not met with or verified in the eastern areas. The deformation magnitude of the wrench faults, and consequent dislocation of the Cretaceous rocks to form discrete highs and lows prior to Eocene transgression, were probably mild or terminated in these sectors. Accordingly, the erosion processes subsequent to upper Cretaceous deformation did not expose, or completely stripped out, the iron ore-bearing rocks, shedding clastics of the Cenomanian deposits (Bahariya Formation). The latter opinion could be confirmed at El Nashfa anticline (along Darb El Bahnassawi) which proved by drilling to be a paleohigh, where the Precambrian granitic basement rocks are penetrated at shallow depths through overlying Cretaceous successions.

The Lutetian and Bartonian facies of these areas are represented mainly by shallow marine and poorly ferruginous bank carbonates and marls, similar to those existing in the areas between the iron-ore hosting localities of El Harra, Ghorabi and El Gedida, although the glauconitic mudstone and greensand interbeds of the Bartonian rocks are intensively bioturbated and highly fossiliferous, reflecting a relatively quiet and open marine circulation. These glaucony facies differ from those existing in El Gedida mine while being isochronous. The latter is very poorly fossiliferous with several syndepositional alteration features suggesting deposition in a very shallow, ecologically unfavourable intertidal flat or estuary. This geologic setting, different from that modeled for El Bahariya mine areas (phases I and II), precludes the possibility of the existence of economic iron ore deposits at least of the Eocene type, in East El Bahariya-West El Minia area.

The disappointing results achieved from East El Bahariya-Nile Valley District, led the work Groups to return to El Bahariya region and to focus their attention and plans on developing the iron-hosting localities, namely, El Harra and El Gedida mine areas. Five development extensions were outlined and subjected to detailed exploration studies using geophysical techniques and a system of shallow pits, trenches and exploratory wells. The outlined extensions comprise:

1. Northeast El Harra (3 km^2).
2. South El Gedida (4,5 km^2).
3. West El Gedida (2km^2).
4. East El Gedida (3km^2).
5. North El Gedida – El Ghaziya (>20 km^2).

These extensions were recommended for exploration as the Lutetian deposits are interpreted to be accumulated near or along the slopes of the Cretaceous culminations and hence, the influences of the above-mentioned controlling factors probably extended to reach these areas. However, the exposed Lutetian rocks in these sectors are completely of karstified carbonate facies, representing the lower and middle parts of the Naqb Formation.

The presence of this carbonate facies minimizes the opportunity to find its equivalent of proper economic pisolitic and nummulitic ironstone. Hence, the planned exploration work in these sectors was restricted to predicting the Lower Cenomanian stratiform ironstones, that assume a thickness ranging from few centimeters up to 10m, and/or the karstified iron ore

Recorded and Documented Reserves (Before 1976)					IEP, Re-evaluated Reserves and New Discoveries (1993 – 1997)						
					Working Group / Exploration Phases	EGSMA		Geology Department Cairo University			
	Locality		Reserve (in Tonage)			Locality	Re-evaluated Reserve (in tonage)	Locality		New Estimated Reserve (in tonage)	Total Reserve in Phases
1	Nile Valley		11,418,750		Phase II (1995 – 1996)	1 North Aweirsha	15.596,822	9c Rod El Kabash		32,917,500	
2	North Wadi Abu Subeira		1,068,813			2 South Aweirsha	11,953,689				
3	South Wadi Abu Subeira		8,032,500			3 Um Huqban	12,784,750				
4	Um Barmil		1,419,000			4 Allawi	34,430,119				
5	Wadi Abu Agag		5,159,700			Total Proved Reserve	74,765,380	Total Geological Reserve		32,917,500	107,682,880 Phase II
6	Um Esh		3,899,438		Phase III (1996 – 1997)	5 Aswan - K. 21	3,000,000	9b Dabaa East		65,289,261	
7	Ras Aqaba		9,129,925			6 Alaqi K. 23	12,000,000				
8	Gabal Timsah		21,490,000			7 Road K. 29	9,000,000				
9	Wadi Um Udi		1,270,500			10 East Um Hebal	100,000,000				
10	Wadi Aweirsha	Re-evaluated in phase II	26,592,843	56,996,468		8 North and Central Wadi Arab	10,000,000	9a Dabaa West		12,558,000	
11	Beida Um Huqban		8,378,825			9 East Wadi Arab	88,000,000				
12	West Allawi		15,951,250			12 End Khor Rahma	11,000,000				
13	East Allawi		6,073,550			11 Barqat Tukham	7,000,000				
14	Gabal El Diheisa		1,803,813			Total Geological Reserve	240,000,000	Total Geological Reserve		77,847,261	317,843,000 Phase III
	Total Reserve		121,688,907		Phase II & III	Estimated geological Reserve = 240,000,000 + 77,847,261 + 32,917,500 = 350,764,761 m.t Proved geological reserve of Um Hebal = 64,000,000 m.t. Additional Proved Reserve (Phase II) = 74,765,380 – 56,996,468 = 17,768,912 Total Proved Reserve (IEP) = 74.765.380 + 64.000.000 = 138,765,380						

Table (3): The previously recorded and newly discovered & re-evaluated iron ore reserves of Aswan Region

type (5-10 m thick) at the base of the Lutetian Naqb Formation. Fortunately the exploratory pits and wells proved the occurrence of these types in the first four sectors.

After the discovery was achieved in south El Gedida and NE El Harra sectors, a close network of wells was penetrated and the geological reserves calculated as shown in Table 4 (IEP achievements in F:I Bahariya Region, 1993 - 1997). Table 4 also includes the previously known ore reserves recorded by EGSMA (1969 – 1971) and UEC (1976), as well as the results of the recent (1987-1997) re-evaluations of the ISCO in Nasser 2 and El Gedida mine areas.

ACHIEVEMENTS OF IEP

The main achievements of the Iron Exploration Project (IEP 1993 – 1997) can be summarized as follow:

1. The IEP clarified the stratigraphy, structure and genesis of the iron ore deposits in Aswan and El Bahariya Regions. Areas worthy of exploration were delineated in both, but with different approaches, since the mode of occurrence of the iron ore deposits in Aswan Region differs from that in El Bahariya Region.
2. The Work Groups integrated the various disciplines of earth sciences to achieve the main goal of this project, i.e. finding new iron ore reserves. IEP added more iron ore reserves totaling about 350 mt (geological reserves) to Aswan, in the south and southeastern sectors, and about 35 mt to El Bahariya Region.
3. The national economy will benefit from the new discoveries of the IEP. The new iron ore occurrences of Aswan feature in the future planning and development of the region south of Aswan. The El Bahariya findings extended the life of El Gedida mine in the Western Desert.
4. The IEP formulated a basis of positive and successful cooperation between governmental institutions, industrial companies (e.g. EGSMA and, HCMI and ISCO, respectively) and research centers i.e. Geology Department, Cairo University. Those engaged in this project re-examined the older genetic models, and experimented with newly introduced concepts, regarding ore genesis.
5. Academic benefits: the young IEP trained geologists from Cairo University, EGSMA and ISCO, and undergraduate students during the field and laboratory studies and investigations. This ferment will grow during the years to come and will generate effective researchers in similar projects.
6. Three Ph.D, and three M.Sc. research programs, on the iron ore deposits and the associated rocks of El Bahariya and Aswan, were supported by the IEP facilities, and the scientific materials realised through the project. Two Ph.D. and two M. Sc. degrees have been awarded during the last few years.

IEP RECOMMENDATIONS

Aswan Region:

1. The extension of the economic oolitic ironstones east and southwards of Aswan should be followed based on the geological parameters outlined in the IEP Reports. The regional southward and south – eastward extensions of the discovered ore occurrences, particularly along Wadi Garrara – Gabal Abraq graben and Aswan Allaqi sector (until lat. 22°) are considered a promising area, recommended for further exploration and prospection.

Area	Area km²	Overb. Thickness (av., m)	Iron Ore Thickness (av.,m).	Cut off Grade Fe %	Reserves (m.t.) -by-			
					EGSMA (1969 – 1971)	UEC (1976)	ISCo. (1987 – 1997)	IEP (1993-1997)
Ghorabi	2.308	0.1 – 2.0	11.1	40 %	55,528,840	56,971,689		
Nasser	1.203	0.1 – 20.0	12.68	30 % (25%)	28,990,760	26,023,281		
Nasser (2) New discovery by ISCo. 1989				30% 40%			10,044,356 7,856,000	
EL Harra	2.9	5.90	8.0	30%	53,744,291	61,226,230		
NE-EL Harra (new discovery by IEP, 1997)	2.4			40%				16,302,809 (40% Fe) 22,937,730 (Fe% ?)
El Gedida	6.464	7.20	10.52	40 %	117,000,000	123,718,000	148,640,358 (re-evaluation)	
South El Gedida (new discovery by IEP, 1995).	0.5							12,650,497 (geological reserve)
Additional Reserves							34,926,714	35,588,227

Table (4): Summary of the estimated ore reserves of the known occurrences and the new discoveries of El Bahariya Region.

Additional Reserves by ISCo.: (Nasser 2+ Re-evaluation of EL Gedida) = 34,926,714
Additional Reserves by IEP (NE EL Harra, & S. EL Gedida) = 35,588,227
Total additional reserves (ISCo + IEP.) = 70,514,941
NE El Harra block (22,937,730 t) = 16,302,809 with 40%Fe + 6,634,921 t (Fe% is not yet available)

2. The essential geological reserves for the discovered ore occurrences must be proved, through detailed trenching and shallow drilling programs.
3. The microscopic examinations of representative thin and polished sections of samples and concentrates are highly recommended to be continued, before and during the further estimation and industrial evaluation and dressing of the discovered ores, taking into consideration the mineralogical and textural parameters (interlocking indices) described and documented in the present work or characterizing the produced concentrates. This will help a lot in the suitable dressing techniques of such ores, in order to avoid the complications and contaminations of the produced concentrates.

El Bahariya Region:

4. Further detailed field investigations due north of El Gedida mine (North El Gedida El Ghaziya Sector) is to continue, since this sector shows geological features suitable for iron ore formation
5. Drilling in the sectors to the east and west of El Gedida mine is to continue to add more reserves.
6. Drilling along the NE master faults of the northeastern plateau of El Bahariya Depression (Ghorabi – El Bahr and El Harra – El Gedida Faults) is highly recommended, to follow up the subsurface topography of the Cenomanian clastics and associated economic ironstone bands.

Acknowledgments

The work Groups of IEP would like to express their utmost thanks and appreciation to: Chemist MOHAMED ADEL EL DANAF, Chairman of the Holding company of Metallurgic Industries, for his continuous support which has had the greatest effect in boosting the Work Group's commitment to implement the goals of the project and achieve positive results during the three phases of the project.

Chemist MOHAMED ADEL EL DANAF is also remembered, with all due respect and appreciation, for his understanding of the difficult nature of the exploration missions and field studies, his continuous personal follow-up of the progress of the research activities, and his appreciation and realistic evaluation of the research results; his guiding comments led to the understanding of the significance of achieving all the research objectives, to raise the quality of the discovered iron ore deposits and to orient the effective preparation of these deposits towards serving the industrial trade activities, and hence, to improving the national economy.

Also, with all affection and gratitude, the Work Groups would like to extend their thanks and appreciation to the follow-up and Evaluation Committee of the Iron Exploration Project (IEP), headed by Engineer Dr. ALI HELMY, Chairman of the Egyptian Company for Iron and Steel (ISCO).

Thanks are also due to the members of this committee: Engineer BAHI EL DIN AHMED; Engineer ABDEL LATIF ALI SOLEMAN; Prof. Dr. ADEL SOLEMAN ABDEL KHALEK; Dr. MOHAMMED ABU EL SAADAT; and Engineer MOHAMED ISSA ABD EL RABOH. The committee's thorough and continuous follow-up of the field exploration and laboratory research resulted in the progress of the exploration philosophy. Its active participation resulted

in, and provided the necessary guidance for, the achievement of the Project aims.

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